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A METHOD AND A DEVICE FOR MEASURING STRESS FORCES IN REFINERS

FIELD OF THE INVENTION

[0001] The present invention relates to a method and a measuring device for measuring stress forces in refiners having refining discs that define a refining gap for refining material.

BACKGROUND OF THE INVENTION

[0002] Refiners are used for refining fibrous material. The refiner generally comprises refining members in the form of discs rotating in relation to each other and between which refining material passes from the inner periphery of the refining members where it is supplied, to the outer periphery of the refining members through a refining gap formed between the refining members. One of the refining discs is often stationary while the other rotates. The refining discs are generally composed of segments provided with bars. The inner segments have a coarser pattern and the outer segments have a finer pattern in order to achieve fine refining of the refining material.

[0003] To obtain high quality refining material when refining fibrous material, the disturbances in operating conditions that, for various reasons, constantly occur must be corrected by constant adjustment of the various refining parameters to optimal values. This can be achieved, for instance, by altering the supply of water to produce a greater or lesser cooling effect, by altering the flow of refining material or adjusting the distance between the refining members, or a combination of these measures. To enable the necessary adjustments and corrections to be made an accurate determination of the energy transmitted to the refining material is required, as well as of the distribution of the energy transmitted over the surface of the refining members.

[0004] To determine the energy/power transmitted to the refining material it is known to endeavour to measure the

shearing forces that occur in the refining zone. What is known as a shearing force occurs when two surfaces move in relation to each other with a viscous liquid between the surfaces. Such shearing force is also created in a refiner when refining wood chips mixed with water. It can be imagined that the wood chips are both sheared and rolled between the refining discs, as well as collisions occurring between chips and bars. The shearing force depends, for instance, on the force bringing the discs together and on the friction coefficient. The normal force acting on the surface also varies with the radius.

[0005] In International Application No. WO 00/78458 a method and a measuring device are known for measuring stress forces in such refiners, the device comprising a force sensor that measures the stress force over a measuring surface constituting a part of a refining disc and in which the measuring surface comprises at least parts of more than one bar and is resiliently arranged in the surface of the refining disc. However, it has been found that this measuring device is very sensitive to temperature fluctuations, which are usual in the applications under discussion, and it therefore often gives incorrect values for the force, which thus cannot be used to control the refining process. Furthermore, a value for the force in only one direction is obtained with this measurement. Another drawback is that other forces also appear that affect the refining segments, such as the normal forces, which are not taken into account.

[0006] One object of the present invention is to solve the problems mentioned above and to thus provide a method and a measuring device that gives a more complete and correct result than previously known devices.

SUMMARY OF THE INVENTION

[0007] In accordance with the present invention, these and other objects have now been realized by the invention of a method of measuring stress forces in refiners including a pair of refining discs juxtaposed with each other and forming a

refining gap for refining material therebetween, the pair of refining discs including at least one refining surface including a plurality of bars for refining the material within the refining gap, the at least one refining surface including a measuring surface comprising a predetermined portion of the at least one refining surface including at least a portion of at least a pair of the plurality of bars, the method comprising resiliently mounting the measuring surface in the at least one refining surface and simultaneously measuring both the magnitude and direction of stress forces in the plane of the measuring surface. Preferably, the simultaneously measuring comprises measuring the stress forces in a first direction by means of a first force sensor and measuring the stress forces in a second direction by means of a second force sensor, the first direction being angularly displaced with respect to the second direction, and determining the magnitude and direction of the stress forces by measuring the stress forces in the first and second directions. In a preferred embodiment, the simultaneously measuring comprises measuring the stress forces in a first direction by means of a first pair of first sensors disposed opposite each other to provide counter-directed readings and measuring the stress forces in the second direction by means of a second pair of second sensors disposed opposite each other to provide counter-directed readings, the first pair of first sensors and the second pair of second sensors being disposed perpendicularly to each other.

[0008] In accordance with one embodiment of the method of the present invention, the simultaneous measuring includes compensating for eccentric normal stress forces on the measuring surface.

[0009] In accordance with another embodiment of the method of the present invention, the method includes measuring stress forces directed perpendicularly to the measuring surface. Preferably, the measuring of the stress forces directed

perpendicularly to the measuring surface includes combining the force exerted by steam pressure inside the refiner and the force exerted by fiber pressure from the refining material. In another embodiment, the measuring of the stress forces directed perpendicularly to the measuring surface includes measuring the force exerted by fiber pressure from the refining material and compensating for the force exerted by steam pressure inside the refiner.

[0010] In accordance with another embodiment of the method of the present invention, the simultaneous measuring of both the magnitude and direction of the stress forces in the plane of the measuring surface comprises calculating both the magnitude and direction from the first and second force sensors, and including controlling the refining process based thereon.

[0011] In accordance with the present invention, this and other objects have now been realized by the discovery of apparatus for measuring stress forces in refiners including a pair of refining discs juxtaposed with each other and forming a refining gap for refining material therebetween, the pair of refining discs including at least one refining surface including a plurality of bars for refining the material within the refining gap, the at least one refining surface including a stress measuring member comprising a measuring surface comprising a predetermined portion of the at least one refining surface including at least a portion of at least a pair of the plurality of bars, the stress measuring member being resiliently mounted in the at least one refining surface and comprising at least a first set of force sensors for simultaneously measuring both the magnitude and direction of stress forces in the plane of the stress measuring member. Preferably, the apparatus includes compensating means for compensating for eccentric normal forces in the plane of the stress measuring member that will effect the measuring.

[0012] In accordance with one embodiment of the apparatus of the present invention, the apparatus includes an additional stress measuring member for measuring stress forces perpendicular to the stress measuring member.

[0013] In accordance with another embodiment of the apparatus of the present invention, the first set of force sensors comprises a first force sensor for measuring the stress forces in a first direction and a second force sensor for measuring the stress forces in a second direction, the first direction being angularly displaced with respect to the second direction, whereby the magnitude and direction of the stress forces in the plane of the stress measuring member are determined from the readings of each of the first and second force sensors. In a preferred embodiment, the first set of force sensors includes a pair of said first force sensors for measuring the stress forces in the first direction and a pair of the second force sensors for measuring the stress forces in the second direction.

[0014] In accordance with another embodiment of the apparatus of the present invention, the stress measuring member comprises a first body connecting the first set of force sensors to the stress measuring member, the first body comprising a first tubular resilient member disposed around the central axis of the stress measuring member, the first set of force sensors being disposed on the first tabular resilient member. Preferably, the stress measuring member includes a second set of force sensors. In a preferred embodiment, the stress measuring member comprises a second body connecting the second set of force sensors to the stress measuring member, the second body comprising a second tubular resilient member disposed around the central axis of the stress measuring member, the second set of force sensors being disposed on the second tubular resilient member. Preferably, the second set of force sensors and the second body comprise compensating means for compensating for eccentric normal forces.

[0015] In accordance with another embodiment of the apparatus of the present invention, the apparatus includes an additional stress measuring member for measuring stress forces perpendicular to the stress measuring member, the additional stress measuring member comprising at least three force sensors disposed on the first tubular resilient member.

[0016] In accordance with another embodiment of the apparatus of the present invention, the apparatus includes an additional stress measuring member for measuring stress forces perpendicular to the stress measuring member, the additional stress measuring member comprising at least three force sensors disposed on the second tubular resilient member.

[0017] In accordance with another embodiment of the apparatus of the present invention, the additional stress measuring member comprises means for measuring the stress force exerted perpendicular to the stress measuring member.

[0018] In accordance with another embodiment of the apparatus of the present invention, the first set of force sensors comprise strain gauges.

[0019] In accordance with the method of the present invention, measuring is performed over a measuring surface that constitutes a part of a refining disc, the measuring surface comprising at least parts of more than one bar and being resiliently arranged in the surface of the refining disc, and forces in the plane of the measuring surface are measured and both the magnitude and the direction of the force are measured simultaneously. The measuring device in accordance with the present invention comprises members for measuring the stress force over the measuring surface, which in turn constitutes at least a first set of force sensors for simultaneously measuring both the direction and magnitude of forces in the plane of the measuring surface.

[0020] The measurement in accordance with the method of the present invention is preferably performed with the aid of at least two force sensors, one of which is arranged to measure

in an X-direction and the other of which is arranged to measure in a Y-direction, and the magnitude and direction of the force influencing the measuring surface are determined as the resultant reading of the two force sensors. It should be pointed out that the X-direction and Y-direction, respectively, do not necessarily imply two directions forming a right angle with each other, but these directions may form any angle at all as long as they do not coincide with each other.

[0021] The present invention thus enables measurement of the shearing forces in two directions, thereby enabling both the magnitude and direction of the resultant shearing force to be determined in any direction at all, which is advantageous.

[0022] In accordance with a preferred embodiment of the present invention the measurement is performed with the aid of at least four force sensors arranged in pairs opposite each other so that the two sensors in each pair give counter-directed deflection or readings, the pairs are arranged at right angles to each other to measure in an X-direction and a Y-direction, and the magnitude and direction of the force are determined as the resultant reading, i.e. the measured stress forces of each pair of force sensors. The use of sensors arranged in pairs giving counter-directed readings offers the important advantage that a value can be obtained for the stress force that is not affected by occurring temperature fluctuations. This is achieved by utilizing the difference between the readings of the force sensors in the relevant pair, measured on each occasion, as the value of the stress force in each direction. This value can then be utilized to calculate the magnitude and distribution of the power transmitted to the refining material and these calculations can then be used to control the refining process. In this context reference is also made to Swedish Patent Application No. 0102845-5 filed by the present applicant.

[0023] Utilizing pairs of counter-directed sensors in the manner defined in the present invention offers the advantage that any measuring errors are halved for each direction.

[0024] In accordance with another advantageous feature of the present invention, the measurement of these forces in the plane of the measuring surface also includes compensation for any eccentric normal forces on the measuring surface that would affect such measurement.

[0025] In accordance with an additional advantageous feature of the method of the present invention forces directed at right angles to the measuring surface are also measured. This method preferably includes measurement of the normal force exerted by a combined pressure consisting of the steam pressure inside the refiner and the fiber pressure from the refining material. An alternative choice is to measure a normal force that is a result of only the pressure of the fiber mat.

[0026] The measuring device in accordance with the present invention comprises suitable devices for performing the method.

[0027] In accordance with a particularly advantageous embodiment of the present invention, the force sensors comprise strain gauges. A particular advantage of this is that the actual measuring device will be relatively small and low, thus allowing it to be fitted directly in the refining segment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The present invention will now be described with reference to the following detailed description, which refers to the accompanying schematic drawings, in which:

[0029] Figure 1 is a top perspective view of a refining segment included in a refining disc which is provided with measuring devices in accordance with the present invention,

[0030] Figure 2 is a schematic representation of a basic layout in accordance with the present invention,

[0031] Figure 3 is a side, elevational, cross-sectional view of a first embodiment of a measuring device in accordance with the present invention,

[0032] Figure 4 is a schematic representation of a basic layout of the embodiment illustrated in Figure 3,

[0033] Figure 5 is a side, elevational, cross-sectional view of a second embodiment of a measuring device in accordance with the present invention,

[0034] Figure 6 is a schematic representation of a basic layout of the embodiment illustrated in Figure 5, and

[0035] Figure 7 is a top, elevational schematic cross-sectional view of the thin-walled tubular parts of the first and the second body, and the strain gauges arranged thereon.

DETAILED DESCRIPTION

[0036] Referring to the drawings, Figure 1 shows a part of a refining disc in the form of a refining segment 1, provided with a pattern comprising a number of bars 3 extending substantially in the radial direction. Measuring devices 4 in accordance with the present invention are also shown schematically in this figure. These measuring devices preferably have a circular measuring surface 2 with a diameter in the order of 30 mm, for example, but the measuring surface may alternatively have a different geometric shape. The measuring devices are preferably arranged at different radial distances from the center of the refining disc, and segments at different distances from the center preferably also have measuring devices. The measuring devices can also advantageously be displaced peripherally in relation to each other to enable them to better determine the power distribution in the refiner and thus better control the refining process. When a measuring device is influenced by forces, each of the force sensors will generate a signal that is proportional to the load.

[0037] The measuring device in accordance with the present invention functions in accordance with the principle illustrated in Figure 2. Shown thereon is a measuring surface 2 in the form of part of the surface of a refining segment, provided with a number of bars 6, or at least parts thereof. The measuring device includes an attachment element in the form of a rod 10, with the aid of which the various parts of the device are secured and which also joins the various parts of the measuring device to each other and to the measuring surface 2. The rod has two fulcrums, a first, upper fulcrum 8 for a first body 5 and a second, lower fulcrum 9 for a second body 7. Compare also Figures 3 and 5. The first body 5 is provided with a first set of power sensors (12 in Figures 3 and 5, respectively). This first body connects the measuring surface 2 with the rod 10 so that, when the refining disc is subjected to a shearing force F_s, the torque M_1 in the first fulcrum 8 or torque point will be:

$$M_1 = F_s \cdot I_1 \qquad (1)$$

where I_1 is the distance between the measuring surface 2 of the measuring device and the fulcrum 8.

[0038] The second body 7 with a second set of force sensors (22 in Figures 3 and 5, respectively) is arranged in conjunction with the second, lower fulcrum 9. This second body is connected to the rod 10 so that, when the refining disc is subjected to a shearing force F_s, the torque M_2 in the second fulcrum 9 or torque point, will be:

$$M_2 = F_s \cdot I_2 \qquad (2)$$

where I_2 is the distance between the measuring surface 2 of the measuring device and the fulcrum 9.

[0039] The torques in the fulcrums are obtained with the aid of the readings of the force sensors and, on the basis of these, the shearing force F_s can be calculated.

[0040] Thanks to the arrangement with a second set of force sensors it is possible to compensate the values obtained for the shearing force F_s with regard to any asymmetric or

eccentric normal forces, i.e. forces in the normal direction, perpendicular to the measuring surface which, due to their point of attack not being the center of the measuring surface 2 since they are displaced from the center, influence the force sensors as if they were shearing forces. The following equations are obtained:

$$M_1 = F_s \cdot I_1 + F_N \cdot I_N \quad (3)$$

$$M_2 = F_s \cdot I_2 + F_N \cdot I_N \quad (4)$$

where F_N is in this case an eccentric normal force and I_N is the distance between the central axis and the point of attack of the eccentric normal force.

[0041] The equations (3) and (4) provide the following expression for the shearing force, which is utilized in the measuring device:

$$F_s = \frac{M_2 - M_1}{I_2 - I_1} \quad (5)$$

[0042] If no eccentric normal force occurs to influence the measuring surface, it would be sufficient with only one set of force sensors and one body.

[0043] Figure 3 shows a preferred embodiment of a measuring device in accordance with the present invention. The measuring device 4 comprises a measuring surface 2 provided with bars 6, or parts of bars, which measuring surface constitutes a part of a refining segment as illustrated in Figure 1. As is also clear in Figure 1, the measuring device preferably has a circular measuring surface. The measuring device and the measuring surface are movably arranged in the refining segment 1, in all directions.

[0044] The measuring surface 2 is in direct contact with a first, upper body 5 extending inside the device. At its lower side this first body is shaped as a thin-walled tube 15. The material is chosen to be somewhat resilient. A cross section through the thin-walled tube section can therefore be likened to a spring, as illustrated in Figure 4. Strain gauges are

arranged on the outside of the thin-walled tube section, which form a first set of force sensors 12. It is actually the thin-walled, somewhat resilient tube section that, together with the strain gauges, forms the force sensors, but for the sake of simplicity the term force sensor is used in this description primarily as a designation for the strain gauges or equivalent members. The strain gauges are preferably arranged axially and when the thin-walled tube is subjected to a load it is slightly deformed so that it influences the strain gauges. These are, in turn, connected to some suitable strain gauge bridge that generates a corresponding signal. The thin-walled tube section 15 is pre-stressed with a tensile force so that it does not risk collapsing when subjected to loading.

[0045] Inside the tube section extends a rod 10 with a spherical top, which rod forms the previously mentioned attachment element. The first body 5 is journalled on the spherical top which thus functions as a fulcrum for the body 5 and forms the first fulcrum 8. This embodiment comprises four sensors arranged symmetrically in relation to a center line extending through the measuring surface 2 and through the rod 10. The sensors 12 are preferably arranged with 90° spacing (see also Figure 7). They are arranged in pairs opposite each other so that the sensors in a pair will give counter-directed deflection/reading when influenced by a force. When the pressure on the measuring surface 2 increases, the load on one of the sensors will increase while at the same time it will decrease on the other sensor in a pair. The stress force can therefore be calculated on the basis of the difference between the readings measured at any one time on respective force sensors in a pair. It would naturally be possible to arrange the sensors differently in relation to each other and still have their respective readings be counter-directed. Said pairs of sensors are also arranged perpendicular to each other for measuring in an X-direction and a Y-direction, i.e. in a plane parallel with the measuring surface 2. This permits

measurement of forces in all directions in a plane parallel with the measuring surface, the magnitude and direction of the force being determined as the resultant of the readings of respective pairs of force sensors (see also Figure 4).

[0046] A second, lower body 7 is arranged below the first, upper body 5 and outside its tubular part 15. This second body also has a thin-walled tubular part 17, arranged outside and concentric with the tubular part 15 of the first body 5 and with the rod 10, and functioning in a corresponding manner, i.e. as a spring. Strain gauges are also arranged on the outside of the second thin-walled tubular part 17. These strain gauges form a second set of force sensors 22 and are preferably arranged axially. They are four in number and are arranged symmetrically in relation to a center line extending through the measuring surface 2 and through the rod 10. In other respects they are arranged in the same way and function in the same way as the sensors 12 of the upper body 5, i.e. they are arranged in pairs and measure forces in X- and Y-direction, see also Figure 7. However, in the example illustrated the fulcrum 9 for the lower body 7 is formed by the central point of a resilient plate or sheet 18 arranged below the body 7 and connected to the rod 10 so that the rod extends through the center of the plate.

[0047] The fulcrum 9 may alternatively be designed as a waist on the rod 10, preferably arranged immediately above the point at which the plate 18 is located (see also Figure 5).

[0048] The rod 10 preferably has screw threading and the first, upper body 5 is preferably screwed onto the rod. The second, lower body 7 may suitably be attached to the rod by means of a nut.

[0049] The measuring device in the example illustrated also comprises means for measuring forces directed at right angles to the measuring surface, i.e. normal forces, i.e. forces in Z-direction as illustrated in Figure 4. The normal force is a resultant of the steam pressure in the refiner and the

pressure exerted against the measuring surface (and the refining segment) by the fiber mat formed by the refining material. For this purpose the measuring surface is resiliently arranged in a direction perpendicular to the measuring surface, also illustrated schematically in Figure 4. In accordance with one embodiment the normal forces can be measured with the aid of additional strain gauges forming force sensors 32, arranged on one or other of the tubular parts, 15 or 17, preferably axially between the already existing sensors, as illustrated schematically in Figure 7. To obtain a fairly correct measurement, at least three force sensors should be used for measuring the normal force, and these should be uniformly distributed. However, the use of four sensors is preferred, as shown in Figure 7, or possibly more.

[0050] The internal parts of the measuring device described above are arranged in a protective sensor housing 20. This housing is provided with an opening at the top, which is adjacent to the surrounding refining segments, and which is closed off from the refining material, by the measuring surface 2 and a resilient seal 16 between the measuring surface and the side walls of the sensor housing. The housing is also closed off at the bottom, towards the stator of the refiner or segment holder if such is used, by a lid 11. The seal 16 is of a particularly suitable, somewhat resilient material, e.g. rubber, so that it can permit the small movements that the shearing forces give rise to in the measuring surface and still provide a good seal preventing steam and pulp from penetrating into the device. The seal preferably also has a dampening effect on, inter alia, the vibrations occurring during operation. In this context it may be mentioned that the load can vary considerably over the refining zone from values in the order of 20N to in the order of 150N, for instance. In the present case, at an estimated mean value of approximately 40N, displacements of the

measuring surface that can be measured in the order of hundredths of a millimeter are obtained.

[0051] Figures 5 and 6 illustrate a second embodiment of the present invention in which compensation can take place for the steam pressure that exists in the refiner and which constitutes a part of the normal force pressure on the measuring surface that is measured with the measuring device in accordance with the first embodiment. As mentioned earlier the normal force F_N, which affects the measuring surface, comprises both the force from the fiber pressure F_{Fib} exerted by the fiber mat formed by the refining material in the refiner, and also the force from the steam pressure F_S that prevails inside the refiner. It is often of interest to obtain a measurement of the fiber pressure on its own. Parts in this figure corresponding to parts in Figures 3 and 4 have been given the same reference numerals. Thus, this embodiment also comprises a first body 5 and a second body 7, each provided with thin-walled tubular parts 15 and 17, respectively, on which a first and second set of force sensors, 12 and 22, respectively, are arranged. The second tubular part 17 is provided with special force sensors for measuring the normal force, in the form of strain gauges 32 preferably arranged axially between the already existing sensors, as illustrated schematically in Figure 7. Alternatively, these sensors for measuring the normal force could be placed on the tubular part 15 of the first body 5. It also comprises a rod 10 and a plate-like spring member 18, preferably in the form of four crossing legs whose function here is to secure the various parts of the measuring device from below. The internal parts of the measuring device are also located in a protective sensor housing 20. Contrary to the embodiment in Figure 3, however, the lid closing off the sensor housing from the stator or segment holder is designed so that a connection exists between the upper side of the measuring surface and the upper side of the surrounding refining segment by means of an

open channel 13 arranged between the side walls of the sensor housing 20 and the surrounding refining segment 1. The aim is that compensation can be achieved for the existing steam pressure when the normal force affecting the measuring surface 2 is calculated. For this purpose the existing steam pressure shall also affect the parts of the measuring device that measure the perpendicular pressure in the direction opposite to the normal pressure, i.e. from below. The lid 11 may thus be made in two parts, an outer part 23 provided with channels and an inner, movable part 24 having a gap between it and the stator/segment holder. The rod 10 is also shaped so that a gap exists between it and the stator/segment holder. Steam can thus penetrate to the gap 25 formed above the stator/segment holder and thus influence the inner part 24, rod 10 and force sensors 32 on the part 17, or possibly other members that have been mentioned and can form said members for measuring perpendicular forces. The steam pressure acting on the measuring surface and the steam pressure acting from below thus cancel each other out and a measurement of the actual fibre pressure can be obtained.

[0052] It should be pointed out that the method and device for measuring perpendicular forces or normal forces, with or without compensation for the steam pressure, can be used as a separate invention and possibly combined with other devices for measuring shearing forces.

[0053] It is also possible to omit the compensation for eccentric normal forces and have only one set of force sensors, one body and one fulcrum in the device.

[0054] It should also be mentioned that it is perfectly possible to use other types of force sensors than strain gauges in combination with thin-walled resilient tubes.

[0055] Although the invention herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present invention. It

is therefore to be understood that numerous modifications may be made to the illustrative embodiments and that other arrangements may be devised without departing from the spirit and scope of the present invention as defined by the appended claims.

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